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Thermal Mass

From The Editor . . .

There is no shortage of commentary these days about the economy and the economic slowdown we are experiencing. There is no need to overstate the case because the slowdown is obvious – in some respects, it's becoming a case of self-fulfilling prophecies. The economic challenges may well be with us for a while, but the world will not end next week. We will not see armies of homeless and destitute like something out of a post-apocalyptic science fiction movie. The sun will keep on shining, folks will still continue to eat, play, fall in love – in other words, life will carry on.

However, the conditions will, or should, force us to reconsider what and how we work and organize our economy. We'll let others focus on that. But as far as the building industry is concerned, and it is a major factor in the economy that will help the recovery, what we do and experience will have an impact on society in general.

In our concern for economic viability, we should not use the slowdown as an excuse to jettison standards. As we try to stabilize and rebuild confidence, we need to keep in mind that this time also offers us the opportunity to rethink what and how we do things, and improve on what we've been doing. We need a vision for the future.

Economic concerns are not the only issues that need to be faced. We also need to deal with the environmental issues we are facing. As a society, and perhaps because of the influence of the previous US government, we've largely denied that the reality of climate change is upon us, and that it is happening because of (and lack of) our actions.

For us in the home building industry, we should be pursuing aggressive energy performance standards, rather than resting on our laurels. There was a time when Canadian standards, such as the R-2000 program, were world leaders. But that time is now past, as others take action. Net-zero energy houses are being built by builders everywhere, although they tend to be individual examples or custom homes.

However, discussion in Britain is that all new homes will have to be built to new zero energy standards by 2016, by regulation. The European Parliament has called on the European Union to propose a binding requirement that all new buildings that need to be heated and/or cooled are built to PassivHaus or equivalent non-residential standards by 2011.

A dwelling is deemed to satisfy the PassivHaus criteria if the total energy demand for space heating and cooling is less than 15 kWh/m^2/yr of heated floor area, and the total primary energy use for all appliances, domestic hot water and space heating and cooling is less than 120 kWh/m^2/yr.

So as we take a breather, we have the opportunity to review and rethink our construction practices and standards. We are going to have to build low impact buildings. We should be moving our building standards to more aggressive goals. Unfortunately, aggressive high performance standards are not going to happen just by voluntary action, but will require some regulations as well.

Richard Kadulski,
Editor

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Thermal mass

A properly designed building can get a significant amount of its heating needs from the sun. However, in winter, the sun is only available for a few hours per day, especially the further north one moves, but the need for heat is greatest then and at night, thus, there is a need to store heat.

An effective way to store the heat from day to night is the holy grail of every passive solar designer. Many materials and approaches have been tried over the years – some work in practice, others only in theory.

Interest in the use of heat storage in a building, to reduce daily temperature fluctuations and to store it for times when heat is needed, has been rekindled recently with the push for more sustainable, energy efficient homes.

In the 1980s there was a flurry of activity with passive solar designs and with different thermal storage approaches. A variety of options were considered, with everything from water, rocks, and paraffin wax, to eutectic salts being tried. A number of projects were studied and monitored but unfortunately, research into renewable energy was curtailed in the early 1980s. Renewable energy programs were shuttered and a lot of valuable resources and documentation was lost. Some research documents and monitoring reports sit in uncatalogued storage boxes in various locations where researchers may have taken their papers – they could offer valuable insights to help update new approaches.

When correctly incorporated into buildings, thermal mass can be a cost effective and useful way of reducing daily temperature variations and to keep building interior temperatures within thermal comfort limits.

Historically, thermal mass has been a primary characteristic of housing in hot climate regions. The traditional use of thermal mass in desert climates such as the south-west US and the Middle East, where outside temperatures swing above inside temperatures during the day and below at night, evolved as a response to the hot days and cold nights of the desert. High thermal mass masonry building shells can store the heat from the outside during the day and release that heat to the inside at night, keeping the inside comfortable using almost no additional energy.

In temperate and cold regions, passive solar design and thermal storage must be combined with energy conservation to be effective.

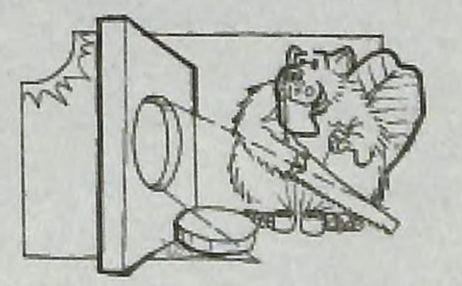
Thermal Mass Principles

Heat always moves from a warm area to a cold one. In a building, solar energy first heats up the air. Then, because the construction materials (floors, walls and ceilings) are cooler, the heat is absorbed and conducted into these materials. When the sun sets and the air temperature inside falls, it will reach a point where the materials are warmer than the room air, and the stored energy will be radiated back into the room. The more mass there is in the home, the greater the amount of energy that could be stored – up to a point.

The principle of thermal mass for heat storage relies on the ability of a material to absorb heat and then slowly release it back into the environment. Every building contains thermal mass – the framing, gypsum board, furniture, brick or stone feature walls and tile floors are all able to absorb and store some heat. Good materials for use as thermal storage have the ability to conduct and store energy, both heat and cold, and to release that energy back into the living space when it's needed.

Thermal mass should not be confused with insulation. Materials used for insulation have a much lower thermal conductivity than materials used for thermal mass and do not have a high capacity to store heat. Insulation materials reduce unwanted heat transfer but they do not store heat in themselves. A combination of good insulation and thermal mass is needed to achieve an optimum solution.

The simplest thermal storage designs are referred to as direct-gain passive systems. These are the easiest and most cost effective way to use solar energy. The structure itself is the solar system. The south-facing windows are the solar collectors that warm the construction materials indoors during the day. The interior surfaces of walls and floors that are exposed to winter sunshine are the storage (mass). A concrete floor (slab-on-grade) that is insulated below,



either left exposed or finished with conductive materials such as ceramic tiles, is a simple example of a thermal mass.

For best performance, it is important to orient the structure and largest window areas as close to true south as possible. Materials with high thermal capacity should be placed with direct exposure to the sun in order to capture the most heat. This can be done as an interior masonry feature wall or concrete and tile floor.

More sophisticated attempts incorporate indirect solar storage. This is where the storage materials are not in the direct sun, and require some form of means to move the excess heat into the thermal storage. Insulated water tanks and rock storage bins are perhaps the most common thermal storage mediums. These indirect systems take the excess heat collected through windows and in solarium spaces and occasionally also active solar collector panels.

Efforts have also been made to use the thermal storage as a seasonal storage. In this case, thermal storage is designed to retain heat collected during the summer for use during the winter. The heat may be captured using solar collectors, as well as using excess heat in the building.

The major challenge for these larger thermal storage approaches is the need to be able to store and retrieve the heat easily, but more importantly to contain the heat. A major reason many thermal storage approaches have failed in the past is the inadequate levels of insulation used for the thermal storage containers.

Thermal Materials

Thermal mass refers to a material's capacity to store heat. All materials can store heat, but the quantity of energy that can be stored depends on the thermal capacity of the material. The ability to store heat varies from material to material and is known as the specific heat capacity. Because the source of heat is the sun, the size and type of windows is an important factor that must also be considered.

Distributed thermal mass – such as a concrete floor or masonry wall – needs to be spread over a large area rather than in a compact volume. Typically, this means a thickness of about 3-4". A thicker mass has too much heat capacity, and will be much more of a heat sink, and will not cycle – in other words, it will not absorb and give off heat on a daily cycle.

For a material to be used in a building for thermal mass, a combination of heat capacity and density is needed. Of common building materials, concrete and stone has the best heat capacity per volume, is inexpensive and easy to work with.

Table 1 lists the heat capacity of typical materials. As can be seen, air has a higher heat capacity than concrete. However, because of the low density of air compared to that of concrete or water, air is not able to hold much heat. That is why forced air heating systems need large ducts to move a lot of air, while hydronic heating systems do it with small diameter pipes.

Water has the best heat capacity per volume, which is why some passive solar designs in the past incorporated tubes or barrels of water to capture and store heat in the house. The problem is that water is a liquid that has to be contained, can leak in the wrong place at the wrong time, and is difficult to incorporate into a building design. ☼

Table 1. Thermal Storage Capacity of Common Materials

Material	Heat Capacity (J/gK)	Density (kg/m^3)	Heat per volume (MJ/m^{3}K)
Water	4.18	1000	4.18
Gypsum	1.09	1602	1.746
Air	1.0035	1.204	0.0012
Concrete	0.88	2371	2.086
Brick	0.84	2301	2.018
Dry sand	0.835	1602	1.337
Granite	0.79	2691	2.125
Wood	0.42	550	0.231

One metric ton of water can store 317,000 BTUs (334 MJ) of energy for each 1°C temperature rise. One cubic meter is 1,000 litres (or the same volume as 500 2-litre jugs of milk).

Raising one cubic meter of water by 10°C will require 3,170,000 BTUs.

Provident House – Follow-Up

We highlighted the Provident House (Solplan Review No. 141, July 2008). This 3,600 sq.ft. Toronto area house which was designed to be 100% solar heated, was built in 1976. It featured a large (716 sq.ft.) single glazed solar collector array and a large (272,000-litre) concrete water tank for seasonal thermal storage. The house has a water storage tank and area.

A technical note in a 1979 issue of *Solar Energy*, a peer reviewed scientific journal, compared the performance of four (including Provident) solar heated houses in Canada, USA and Denmark.

Monitored results in the first couple of years showed that the house did not achieve the 100% solar heating it was designed for, largely because of malfunctioning pumps, valves, automatic controls and leaks.

This was a common issue with systems in the other houses compared. The summary of the review suggests that it is much more important to focus on energy conservation (higher insulation levels, more airtight construction, heat recovery ventilation), good solar orientation to maximize passive solar gains, use of insulating shutters on windows, and than use of high efficiency solar collectors and other complex mechanical systems. ☼

Water thermal storage

Not many years ago ice was used for cooling. Blocks of ice were moved from the mountains or underground storage caves into cities where it was used in ice-boxes (for food refrigeration before the wide spread availability of refrigerators) and also to help cool buildings.

The original definition of a "ton" of cooling capacity was the amount of heat needed to melt one ton of ice in 24 hours. This was approximately the amount that an average 3,000 square foot house in Boston would use in a summer day. Today mechanical engineers still refer to tons of cooling, but it means 12,000 BTU/hour.

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Monitoring Results of Rain-screen Walls

Building envelope failures in buildings built in the late 1980s to the mid1990s on the West Coast generated considerable study and review to determine what went wrong. Unlike historical cold-climate moisture problems, caused by vapour diffusion or air leakage from the interior, failures on the West Coast were caused mainly by rainwater penetration into face-sealed or concealed barrier wall assemblies. Typically, water entered at boundary locations between different materials and became trapped within the wall assemblies, where it could not drain or dry out.

As a response to the leaky building crisis, rain-screen wall assemblies became standard construction practice throughout coastal BC, and have now been enshrined into the building code.

The basis of a rain-screen wall assembly is that it is more tolerant of moisture penetration because it allows for drainage of the moisture, and an increased potential for drying, significantly reducing accumulation of moisture within sensitive materials.

To verify performance, an industry-sponsored program was established to monitor the long-term performance of rain-screen walls in five Vancouver buildings – three new and two rehabilitated residential buildings.

At least five different rain-screen wall locations were instrumented with sensors to measure temperature, relative humidity (RH), moisture content, relative wetness and pressure differential within the wall assemblies at areas most likely to be wetted during severe weather. Key details such as vents, windows, balcony transitions, and saddle flashings where historically high moisture levels have been observed were also checked.

It was noted that location of insulation, ventilation behind the cladding, exterior and interior environments and detailing, all influence rain-screen wall performance.

Six years of monitoring show that rain-screen walls work well in Vancouver's coastal climate. Seasonal moisture levels in wood and gypsum materials, most sensitive to moisture damage, remain below safe thresholds. However, it was also found that rain-screen walls, like all wall assemblies, are susceptible to damage if exposed to excessive moisture at vulnerable construction details.

Moisture Content Varies Seasonally

It is important to understand that there are seasonal variations in wood moisture content. Also, moisture content measurements vary with temperature, wood species and engineered board product, so readings must be interpreted accordingly.

During mild and rainy winter months, the sheathing behind the cladding will be exposed to RH levels of 80-100% for prolonged periods, which results in a moisture content of up to 20% (based on equilibrium conditions with the average RH). During prolonged rainy periods, it is normal for the sheathing moisture content to reach up to 25% for a few days when the rain-screen cavity RH is at 95-100% RH.

In the strapping or sheathing, a sustained (more than 1 month) moisture content of 20 to 30% indicates long-term exposure to high RH levels (90%+) within the rain-screen cavity. This could be the result of a rainwater leak into the cavity, condensation or poor ventilation of the rain-screen.

Detailing is Critical

Even with more moisture tolerant rain-screen wall assemblies, proper detailing of penetrations through the wall assembly (pipes, vents, etc.) and transitions between walls and adjacent elements (windows, balconies, roofs, etc.) and changes in materials, remains very important.

The type of moisture damage observed in the past with face-sealed or concealed barrier approaches will not likely happen in rain-screen wall assemblies. However, localized moisture damage and microbial growth may still result from water penetration or excessive moisture loading. Thus, construction details must ensure that water can drain out and that the assembly can dry out rather than trapping water within the wall assembly.

During the study, two rainwater leaks were spotted in the conventional, strapped-cavity rain-screen walls. One occurred at a poorly built flashing termination (an exhaust vent through vinyl siding). Small amounts of water infiltrating

over time raised the sheathing moisture content up to 30% for several weeks during the first winter. Drying did not occur until spring only after the detail was disassembled and the deficiency was corrected. Left uncorrected, localized damage to the plywood sheathing would have been likely.

The second leak past the cladding happened below a window corner subject to high rainwater run-off. During a severe winter storm, water penetrated the stucco and wetted the wood strapping but not the sheathing. For the remainder of the winter, the strapping had high moisture levels, only drying out in the spring.

Wood strapping will likely be exposed to occasional wetting during severe storms in most walls, especially where it is exposed to run-off, so treated wood strapping is recommended.

The type of cladding is less critical to the performance of a drained and ventilated rain-screen wall than in traditional wall assemblies. Stucco, fiber-cement board and vinyl siding all had similar performance.

Rain-screen Walls Benefit From Cladding Ventilation

The function of the airspace between the cladding and the back-up construction of a rain-screen assembly is to provide a capillary break, allow drainage and ventilation. Drainage removes any water that penetrates past the cladding. However, drainage alone cannot remove small droplets of water or water that is absorbed into the sheathing, strapping or cladding. Ventilation (air movement) has a significant impact on the performance of rain-screen walls. A 3/8" to 3/4" continuous gap behind the cladding, which is common for most residential construction, is generally enough.

This airspace is usually created with vertical strips of treated wood strapping/furring, metal girts, or proprietary products. Some proprietary drain-mat products are impermeable to vapour, so ventilation is critical and extra care must be taken not to block any of the vent openings with these systems.

Ventilation of the rain-screen cavity reduces the relative humidity in the cavity and helps dissipate the small amount of water that may get past the cladding and through penetration details from time to time. Absorptive siding materials such as brick, stucco, or cement board can also introduce water vapour into the rain-screen cavity as the moisture evaporates in both directions. The cavity ventilation can also remove this moisture.

If ventilation rates are not enough, an inward vapour drive could result in higher moisture levels within the wall structure behind the cladding. To ensure adequate ventilation, large and unrestricted vent openings should be provided through the cladding. Continuous cross-cavity strip vent openings are ideal. Discrete vent openings (such as the ones used in brick veneer) are also effective but they can reduce the ventilation flow and result in moisture ingress if designed or built incorrectly.

Venting of the wall cavity at both the top and bottom of each wall section is the most effective and allows for continuous natural air movement. Where the top of the wall ends at a curb or parapet, top vents must be protected from rainwater penetration by a flashing or baffle. The termination of a wall at the soffit should not allow for the rain-screen cavity to vent into the attic.

Consideration for building shrinkage or sustained deflection must be made to prevent cladding ventilation gaps from closing up. Cross-cavity vent openings should be designed to account for normal floor-to-floor wood shrinkage.

Overhangs Are Good

Roof overhangs and other projections such as balconies or eyebrows reduce the amount of driving rain against sensitive cladding interfaces and details. Reducing the wetting of a wall naturally reduces the risk of moisture damage.

In a *rain-screen* wall the exterior cladding (masonry, siding, panel or stucco) is separated from the structural wall by a cavity to provide a capillary break that allows the drainage of any moisture that might penetrate past the cladding. It also allows ventilation of the cavity to promote drying. The rain-screen gap increases the durability of both the cladding and the back-up wall assembly.

Face-sealed or *concealed-barrier* assemblies rely on the cladding or the concealed membrane behind the cladding to stop all water penetration. They do not allow for drainage from the back-up wall assembly or have good drying capabilities.

While the annual rainfall amounts recorded were similar across all five buildings monitored, wind speed differences, particularly at the four-storey buildings, account for the large differences in actual driving rainfall. Buildings with large overhangs (24-48″) received much less driving rain than those buildings with no overhang or with overhangs less than 12″. A 48″ overhang on a relatively sheltered four-storey building can reduce driving rain on its façade to negligible levels.

Interior Moisture Also Needs To Be Considered

The indoor environment is a critical design factor for wall design. The measured interior conditions varied across all five buildings and none could be considered average for design standards (i.e. 21°C year-round). The temperatures varied because of occupant behaviour and the interior dew-point and RH varied considerably as a function of moisture generation and suite ventilation rates.

None of the monitored buildings have air conditioning, so average interior temperatures of 25-27°C were normal during July and August. Interior temperatures of up to 34°C were recorded during the hottest summer days. Some low interior wintertime RH levels (less than 40%) were measured. Suites with low wintertime RH levels (30 to 40%) had sufficient – and in one case excessive – ventilation rates. High winter RH levels (between 50 and 70%) were only observed in one building, and that was attributed to insufficient ventilation and occupant behaviour.

Air Leakage within Multi-Unit Residential Buildings is An Issue

As part of the study, air leakage testing was performed to understand and quantify air leakage in multi-family buildings. Four buildings affected by interior humidity problems were tested. Although this portion of the study is especially relevant for the apartments studied, there are lessons for all types of attached dwellings, including row houses and duplexes.

Results showed the impact that inter-suite air leakage and enclosure airtightness has on the dwelling ventilation rates, interior RH levels and on wall performance.

Significant air leakage occurs between adjacent suites and between suites and common areas within multi-unit residential buildings. These interfaces should be airtight for noise, odour and fire/smoke control reasons.

Up to 2/3 of the hourly air exchange was found to come from adjacent suites and corridors (not the exterior). Many residents weather-strip or block off door-undercuts to reduce noise and odours. This makes the problem worse, as air from adjacent suites is drawn in instead. Ideally, fresh air should be ducted into each suite directly, bypassing the corridor spaces.

The more airtight the exterior enclosure (as in new construction or rehabilitation work), the more the inter-suite air leakage becomes a significant issue.

Common apartment mechanical systems using pressurized corridors and in-suite mechanical exhaust don't work well in airtight buildings unless in-suite exhaust with sufficient makeup air is provided.

Rain-Screen

- ♦Rain-screen wall assemblies are effective in managing exterior moisture loads from wind-driven rain.
- ♦Appropriate detailing and construction of interfaces and penetrations are important for the success of rain-screen assemblies.
- ♦For greater durability, wood strapping/ furring used for the rain-screen cavity should be treated wood.
- ♦Plywood or OSB sheathing will be exposed to high relative humidity and borderline safe moisture content levels for several months of the year (~20%) in coastal areas. Treated plywood may provide an additional safety factor for high exposure buildings.
- ♦Consider an entirely exterior insulated wall assembly for improved performance and increased moisture tolerance.
- ♦Cladding ventilation reduces inward driven moisture from absorptive claddings.
- ♦Roof overhangs significantly reduce the amount of driving rain on a building façade.
- ♦High RH levels within suites may develop as the result of insufficient ventilation systems within modern airtight buildings.
- ♦Care must be taken to avoid air leakage between interior suites and provide a balanced mechanical system.
- ♦Mechanical system revisions should be considered when rehabilitating the building enclosure.

Rehabilitated buildings will likely require mechanical system revisions to account for tighter building enclosures. If not, then interior humidity and condensation problems may develop.

Continuously running or automated timer, low-noise bathroom and kitchen exhaust fans may be needed to provide adequate ventilation within suites at certain times of the year. In addition, makeup airflow needs to be provided by passive vents. With continuous ventilation, heat recovery ventilators (HRV's) may be warranted in order to reduce energy costs.

HVAC Design &Rehabilitation Considerations

While an airtight building enclosure is necessary for energy efficiency and thermal comfort, it requires effective mechanical ventilation systems. Airtight buildings place higher demands on the mechanical ventilation systems. Deficient systems can have serious ramifications for building performance and occupant comfort.

This is especially important when rehabilitating to increase the airtightness of a building enclosure. In older buildings, high levels of air leakage have typically been allowed both through and around window and wall assemblies.

Mechanical system designers have assumed that a significant portion of a building's overall ventilation requirements would take care of itself. When such a building is rebuilt to reduce water infiltration and repair damage to wall components, the conventional sheathing paper is typically replaced with a continuous and sealed air and watertight membrane. The windows are often replaced with higher performance windows that are more air and water- tight, and sealant is used around all penetrations and joints.

Thus, the air leakage of the rehabilitated building enclosure is much more airtight than the original construction, so any previous assumption of exterior air leakage is no longer valid. The percentage of inter-suite stale air leakage was found to increase after rehabilitation, when the air exchange to the exterior was reduced. After the rehabilitation, the interior relative humidity increases unless ventilation capacity is adjusted accordingly or occupants keep their windows open. ☼

So you think rainscreens are a recent discovery? This photo was spotted in Toronto, showing the proud members of the church building bee that erected the building. What is interesting to note is that the vertical strapping, prepared for the siding creates a rainscreen. The builders may not have called it that, but would know how to build a building to deal with the weather.

It seems that in our rush to innovate and simplify construction, we may have ignored basic construction principles. Rain-screen detailing is appropriate in all parts of the country, yet we see it used only in known moist maritime climates where problems have led to its being made mandatory.

Extracted from: **Builder Insight Bulletin No. 6** by the Homeowner Protection Office (HPO) and prepared by RDH Building Engineering Limited based on the study HPO, BC Housing and CMHC *Performance Monitoring of Rainscreen Wall Assemblies in Vancouver, British Columbia* by RDH (*www.rdhbe.com*), and further graduate research at the University of Waterloo by Graham Finch *The Performance of Rainscreen Walls in Coastal British Columbia.*

Further information also available in the publication: *Building Envelope Guide for Houses Part 9 Residential Construction*, Homeowner Protection Office, 2007. Available at *www.hpo.bc.ca.*

Letters to the Editor

Re: Vapour Barriers (Solplan Review No. 143, November 2008)

I read with interest the article in the November issue on moisture. As a manufacturer of Structural Insulated Panels (SIPs), our company has completed several studies on moisture and thermal migration of energy.

At the moment we have a study underway by Dr. Tony Shaw. We are monitoring thermal energy loss/gain and moisture migration in an envelope over a two-year period. Measurements are being taken in the envelope of a two-storey home that was built using SIPs except for four-foot sections of wall, floor over garage, and ceilings, which are built using conventional details (i.e. 2x6, R 19 batt etc.) The home is occupied by a family. Data is recorded in 5-minute intervals so that we will have an excellent window to see how the two systems perform in winter and summer.

The last study we did on two identical houses (except that one was SIP and the other conventional 2x6) revealed some interesting results.

What caught my attention in your item was the letter to the editor from Darren Onyshko. When he installs the vapour barrier over the studs and headers using a caulk seal, he is actually one of very few builders that is complying with the scope of the Ontario Building Code. And I understand that the OBC mirrors the NBC, thus he complies with it also.

The Code very clearly states that "Vapour barriers shall have a permeance not greater than 60ng/(Pa•s•m²) (.078PERMS INS), Measured in accordance with ASTM E96, "Water Vapour Transmission of Materials", using the desiccant method (dry cup)." ASTM E 96 clearly specifies how a vapour barrier must be tested and should work as per that test.

By installing a veneer finish over the poly, the vapour barrier is punctured to the extent that it allows water to penetrate through it. And if gypsum with a perm rating of 1373 ng/(Pa•s•m²) was used as a veneer finish, it is easy to understand the phenomenom that is evolving, especially in cold climates.

As a manufacturer and supplier of SIPs for 30 years, I can say that we have never had a vapour, mould or thermal issue as noted with stud construction. It may be time to stop placing bandages on a system that has spent its time and move on, but then there wouldn't be much to research and write about.

Emil M. Taraba
Thermapan Structural Insulated Panels Inc.
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Thanks for the comments. We look forward to hearing the results of your current study.

It is important not to confuse the function of the vapour barrier with that of the air barrier. Moisture in the air (water vapour) does not pass through a 6-mil poly sheet, however, the 6-mil poly is usually relied on to do both functions – it is caulked and sealed in order to be the air barrier, and also functions as the vapour barrier.

We know from research that air movement is the major driving force for moisture into a building assembly, and not vapour diffusion. The fact that a sheet of drywall, or other material is nailed into the structure through a membrane, does not mean that it will automatically be a source of air leakage.

Yes, the fasteners penetrate the sheet material, but the fasteners penetrating the sheet remain snug, otherwise there would be little holding the materials together. Regardless whether it is nails or screws, gypsum board forms a fairly continuous, airtight surface. Where there may be problems is when there are deliberate penetrations, such as cables, pipes, conduits, electrical outlets, windows, etc. that are not properly sealed. It is these joints and splices that form the major sources of air leakage in a building envelope, and with that air leakage, a path of moisture movement.

The code has defined the criteria for materials that can function as vapour barriers and air barriers, but the code is silent on the building as a whole system, as it would be difficult to try and enforce universal air tightness for all building types.

The code's definitions for vapour barrier are set rather arbitrarily at 60ng/(Pa•s•m²). A material with a vapour permeance of 65 or 75 ng/(Pa•s•m²) may not meet code, but it would still offer essentially the same vapour diffusion resistance performance. However, it is the total building air tightness that is much more important.

I suspect that what you are seeing with SIP structures is better performance because of the inherently more airtight construction assembly that is attainable using rigid, fairly airtight insulation and the panelization. Although stick framing can be made airtight, it generally requires more effort than the use of panels. Ed.

Re: Editor's comment on letter from Darren Onyschko, Burlington (Solplan Review No 143, Nov. 2008)

I doubt very much if the "R-value" used in HOT-2000 is representative of the basement wall treatment described by Mr. Onyschko. He describes it as a free-standing metal stud frame with an air space between it and the concrete foundation wall. As such, the air space isolates the frame from the concrete and no conductive heat transfer occurs and no lateral heat flows from the stud in the concrete. Heat flow occurs only by radiation and convection across the space.

It should also be recognized that the steel studs have no moisture content and unlike the wood studs make no contribution the "trapped moisture" in the wall assembly. In the past (Division of Building Research /National Research Council) we always felt that do-it-yourself construction was preferred since the slower rate of construction resulted in the wood studs getting a longer drying period than if a speedy contractor was involved.

It is true that with moisture present, there might be a chance for corrosion, but little chance for mould growth unless the poly barrier (a sheet against the concrete) is ineffective in preventing condensation from the concrete moisture wetting the paper backing of the drywall. Leaving out the poly is no guarantee that condensation from the concrete moisture will prevent mould from moisture collecting on or in the drywall if less permeable paint, tiles or wallpaper is applied as an interior finish.

Gus Handegord
Oakville, ON

HOT-2000 and EnerGuide Ratings

I was reading November's Solplan Review (No.143) and saw that CMHC and NRC had developed a modified evaluation to achieve the 100+ EnerGuide rating for the Riverdale house. I appreciate the reasoning behind having a standard 24kwh per day for light and appliance energy use for EGH rating calculations in HOT-2000, but it penalizes those who have purchased Energy Star appliances and/or use high efficient lighting and/or ECM motors for HVAC.

Is this a version of HOT-2000? Is it/will it be available for mass use? I have used HOT-2000 in general mode for more specific energy calculations, but the EGH number would be nice.

Mike Stuhec
Yellowknife, NT

The standard daily electrical energy consumption value HOT-2000 uses has historical roots, based on the best available information about energy consumption in homes. In truth, we don't really know how much electricity is used. We may be seeing more energy efficient appliances (labelled as Energy Star) but the electrical savings of these is offset at least in part by the larger number of electricity consuming appliances in a home today. As we mention in another item in this issue, NRCan is now launching a study to try and determine what the electrical consumption is in a home today.

The modified EGH index used for the Equilibrium houses involves a manual calculation. The current EnerGuide formula embedded in HOT-2000 has an upper value of 100 – so that theoretically a net-zero energy house would rate 100. However, because of the way the formula is structured, EnerGuide default assumptions and HOT-2000 calculations, the largest number that will be generated with HOT-2000 is a value in the low 90s.

In part this is because of the standardized default assumptions that are used. Like the assumptions used when assessing appliance or vehicle performance, they offer a basis of comparison between different houses (or vehicles) rather than specific performance simulations. To reconcile actual energy use in a specific house, and when other than standardized defaults are used, the HOT-2000 needs to be used in "general mode". Ed.

Canadian Home Builders' Association

Technical Research Committee News

Electrical Energy Use Audit

We are building increasingly energy efficient buildings. Today we are beginning to build homes without conventional heating systems that are liveable in the cold Canadian climates.

Space heating accounts for more than 50% of a typical home's energy use, and domestic hot water load represents another 25-30%. The balance is the energy used inside for lights and appliances. Precisely how much electricity is used for these loads is unknown, although it is increasing. Utility figures for these energy loads are, at best, guesses based on long-term records.

However, with the technological changes in recent years, we have a whole range of new products in our homes – from more sophisticated entertainment systems, to communications equipment to more energy intensive lighting and controls. They all consume electrical energy, even when in the 'off' position. Those instant-on TVs, DVD players, cable decoder boxes, computers, printers, phones, battery chargers, and other equipment all consume electricity, even when not turned 'on'. Some appliances, such as TVs, use up to 50 watts in standby mode – this is the same as if a light were left on in the room.

Even the little cell phone and battery chargers draw electricity when plugged in – even if they are empty. These power draws, also referred to as phantom loads, are increasing, but no one knows by exactly how much, although current estimates are that 5-10% of a home's electrical consumption is for standby loads. Since almost all small appliances have standby consumption, the increased number of appliances per house has effectively cancelled out the efficiency gains on individual appliances.

But we know that these internal loads also represent a significant heating source – acceptable during the heating season, which is short in a well-insulated house, but in excess during the summer. In regions and at times where air conditioning is a consideration, these internal loads can contribute substantially to the cooling loads. That is why NRCan is launching an audit for typical electrical energy use in a home. The intent is to try and establish just how much power is consumed, on average, for lights and appliances inside an average home today.

One design approach that is emerging from the net-zero energy home movement is the concept of "green plugs" for the home's electrical system. In this approach, only some electrical plugs are continuously energized to maintain electricity for those appliances that need to be plugged in constantly – such as the refrigerator, a house clock, the phone and security system. All other plugs that serve lights, appliances and entertainment that have an intermittent use, are then connected to circuits that have a 'kill' switch so that when the occupants leave home, a central switch is turned off, and all the electrical circuits are de-energized.

New regulations are being drafted that will ultimately reduce the standby loads by 75 percent per household.

Radon

Health Canada has revised the guideline for safe limit for average annual radon exposure in homes to 200Bq/m^3 (from 800 Bq/m^3). This brings Canadian standards in line with that of other countries. A public education campaign is to be launched this year.

Radon is a colourless, odourless and tasteless radioactive gas. It is formed by the breakdown of uranium, a natural radioactive material found in soil, rock and groundwater. Radon escapes from the ground into the outdoor air where it is diluted to low concentrations and is not a concern. However, radon that enters an enclosed space, such as a home, could accumulate to high levels.

Radon breaks down to form additional radioactive particles that can contaminate the indoor air. The only known health risk associated with exposure to radon is an increased risk of developing lung cancer.

Builders and renovators need to understand the implications of this change. It is important to realize that radon levels can only be determined by testing over a period of time during the winter. So for new construction, it is not possible to be certain of radon concentrations, even when the house is completed. However, it is important to remember that when building a new home in a region where radon is known to be a concern, details that permit future remediation, should it be needed, can be done easily.

Code changes are still being developed, and will be prescriptive but will place the onus on the homeowner to test their home after occupancy. The main line of defence at the outset is to ensure the basement has a good air seal, sealing all joints in the foundation walls and floors and to provide granular material under the air barrier.

Additional requirements for areas with known radon concentrations will likely involve the installation of a pipe through the basement floor into the granular material, and capped to allow future retrofit of a sealed pipe and vent fan to the outside.

When radon is identified as an issue that needs to be dealt with the principal remediation approach is to air seal the foundation and depressurize the soil under the house.

Renovators will want to advise their customers to have their homes tested when planning a renovation, and become familiar with remediation techniques. This could also become another service they offer.

It is likely that training and certification programs for both radon testers and remediation contractors will be established.

CMHC has a fairly comprehensive and readable publication on their website: ***Radon, A Guide for Homeowners*** (publication number 61945).

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.
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Roof Edge Insulation

Sometimes it takes extreme conditions to highlight the importance of attention to details. The extreme weather on the West Coast this winter generated picturesque snowy images not often seen in this part of the world. Most of the time, the only icicles one sees are the imitation ones created by decorative lighting.

We received this image from a reader in Nanaimo, BC. The house on the right sports faux icicles in the Christmas light string. The house on the left has real icicles growing on the eaves.

Both houses seem to have reasonable ceiling insulation, as seen by the snow pack on the roof that hasn't melted. However, the icicles on the house on the left suggest there is enough heat loss around the eaves to melt, which then forms the icicles.

We are told the house on the left is a conventionally built house. The standard practice in the area means the roof framing has a 6" heel height. The window headers are 2-2x10 with some batt insulation filling in the gap between the header framing and the balance of the 2x6 stud space. This results in significantly lower insulation levels in these areas, thus creating a thermal bridge.

The house on the right is built with structural insulated panels (SIPs). These are structural panels composed of a 5 ½" expanded polystyrene foam insulation with OSB skins. Although the roof is a truss roof, they have a 12" (raised) heel.

The cold weather also provided a visual picture of heat loss through thermal bridges.

The house on the right is a SIP home so there are warmer headers over the windows with solid 5 ½" foam cores, and the roof has a 12" heel height. The house on left is conventional frame with 6" heels and under-insulated window headers.

Energy Answers

Rob Dumont

What is the Factor 9 Home?

The Factor 9 Home (*www.factor9.ca*) is a demonstration home built in Regina, Saskatchewan focused on very high levels of energy efficiency, renewable energy, and water conservation. Although not net zero in energy use, it can be considered to be Net Zero Ready (NZR). NZR is a fancy way of saying that the house could be readily upgraded to Net Zero Energy performance without major structural changes. The house was completed in April 2007.

A photo of the south-facing rear of the Factor 9 Home is shown in Figure 1.

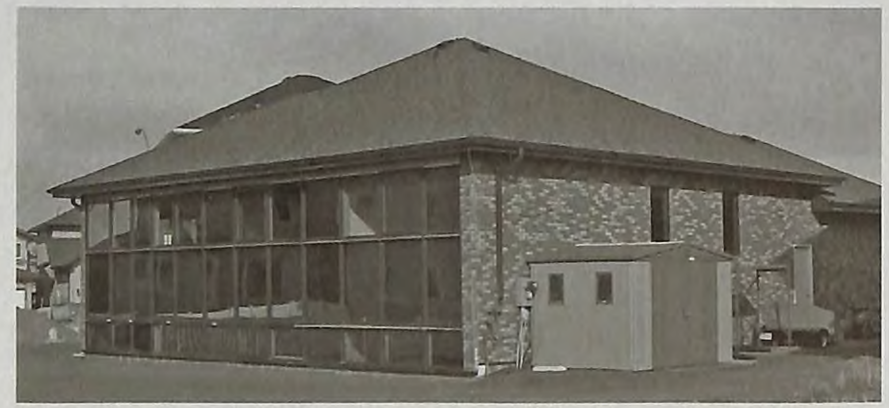


Figure 1. View from the south-east of the Factor 9 Home. The active solar thermal panels are in a horizontal band on the south wall between the main floor windows and the basement windows.

The house features a very energy conserving envelope, with attic insulation levels of RSI 14.1 (R80), above-grade walls of RSI 7.2 (R41), and basement wall insulation levels of RSI 7.7 (R44). At the rim joist area, the insulation level is RSI 4.7 (R26.9). The building was well sealed, with a measured air tightness level of 1.2 air changes per hour at 50 pascals, which is tighter than the R-2000 standard of 1.5 ac/h at 50 Pa.

Passive solar heating was used to provide part of the space heating (passive provides about 41% of the total annual space heating requirement). Active solar heating is used with 20.4 square meters of double glazed vertical solar panels mounted on the south wall of the house. The south wall faces 26 degrees east of due south. A 2,350 litre water storage tank in the basement is used to store the heat from the solar panels. To distribute the space heating for the house, a fan coil with a brushless direct current fan motor is used.

The active solar panels are used to provide part of the domestic water heating and some of the space heating. A passive drain water heat exchanger is used to preheat the domestic hot water prior to the solar storage tank. An instantaneous electric heater is used to provide the auxiliary energy needed for domestic water heating.

Energy Star white appliances were used, along with compact fluorescent lighting. The Energy Detective™ electricity use monitor was used by the occupants to closely track their electricity consumption.

The house was monitored for energy and water consumption over the period from June 1, 2007 to May 31, 2008.

How well did the Factor 9 Home perform during the year of monitoring?

Over the one-year period of occupied monitoring, the measured purchased energy consumption of the house was 33 kilowatt-hours/ square metre of floor area. For comparison, a typical home of the same size built in 1970 would have a consumption of 331 kWh/sq.m. A graphical comparison of the energy consumption of the two houses is shown in Figure 2.

The reduction in purchased water use by the

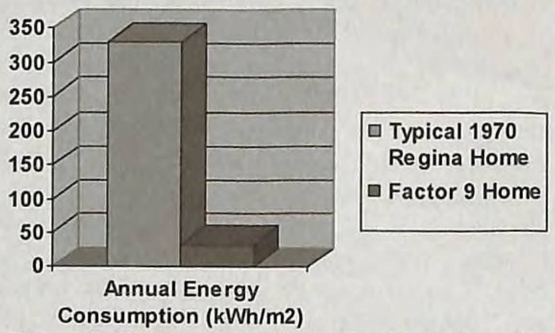


Figure 2. Comparison of the annual purchased energy consumption of a typical 1970 Regina Home with the Factor 9 Home

home was also quite dramatic. For a family of 4 persons, the average water consumption in Canada is 501 cubic metres per year. For the one-year monitoring period, the measured water consumption of the Factor 9 Home was 171 cubic metres, a reduction in purchased water use of 66%. In the monitored year, the total precipitation was

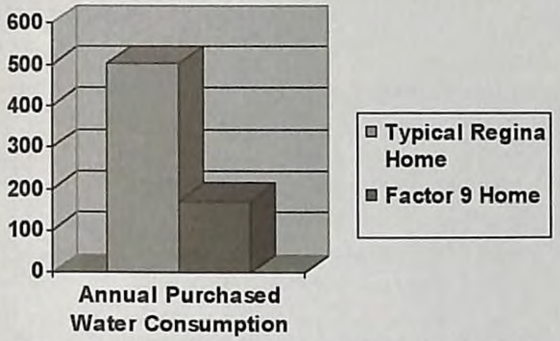


Figure 3. Comparison of the annual purchased water consumption of a typical Regina Home with the Factor 9 Home

less than half of the long-term average of 388 mm for Regina, reducing the amount of water able to be gathered by the roof collection system. The exterior landscaping for the home was not completed during the one year of monitoring. Water collected on the roof is directed to two membrane tanks with a combined volume of 22 cubic metres located in the crawl space beneath the basement floor. The annual average rainfall in Regina on the roof of the house is about 38 cubic metres.

What were some lessons learned from the project?

1. A very high energy performance home in a cold climate has been successfully demonstrated. The measured energy consumption of the house (33.1 kWh/m^2) was about 10% higher than the energy target (30 kWh/m^2) for the house for a one year period. Conventional 1970-1973 vintage homes had a measured annual energy consumption of 331 kWh/m^2 per year. The average home in Canada uses 8,760 kWh per year for lights and appliances. (CREEDAC, 2001). The Factor 9 Home used 8,684 kWh of electricity plus a quantity of wood equal to approximately 1,292 kWh of useful space heating.
2. The participation of the homeowners was a substantial contribution to the achievement of the energy and water conservation goals. The use of The Energy Detective™ to allow the occupants to determine their instantaneous use of electricity was of considerable value in minimizing the energy use.
3. The homeowners did a substantial amount of the work on the house and were able to achieve discounts through their professional contacts. Thus, it is difficult to put a precise number on the incremental cost of the energy and water efficiency features. The incremental construction cost for the energy and water efficiency measures for the home was roughly $37,000, or 10% extra. The home includes a number of upgrades that increase the durability of the home, including a piling foundation in the Regina clay soils, exterior insulating brick cladding, and upgraded asphalt shingles. The water savings are $488 per year based on current water prices in Regina. The house does not use any natural gas. The energy savings compared with a new home of similar size located in Regina (that is heated with natural gas) are estimated at $952 per year based on reference data in the CREEDAC database of homes built between 1998 and 2000. The combined energy and water savings amount to $1,440 a year based on current energy prices in Regina. The rate of return on the incremental costs for the energy and water-saving features of the home is thus 3.9% per annum based on current energy prices. This would be equivalent to a simple payback period of 26 years. In a number of Canadian provinces, substantial cash grants are now available to help reduce the incremental cost of the energy efficiency measures. These cash grants would improve the economics.
4. Several additional energy efficiency measures are recommended to further reduce the energy consumption of the house. Insulation should be added to the basement floor to isolate the floor from the crawl space[1]. A relatively inexpensive way to add insulation is to place heavy-duty aluminum foil on the base of the wood trusses in the basement floor. If RSI 1.8 (R10) insulation is added to the floor in the crawl space, an annual energy saving of about 1,225 kWh could be achieved. This additional insulation would bring the annual consumption down to a value of 29.1 kWh/m2 or better than the target value of 30 kWh/m2. In addition, the basement air temperature would be raised to a more comfortable level during

[1] The basement in this house has a suspended wood floor, with a crawlspace under the basement floor. This is a common detail used in parts of the prairies with expansive clay soils – walls define the foundation, but there is no concrete slab floor because of the clay movement.

the heating season. A shiny surface facing down has a metric R value of RSI 1.8 (R10). In addition, further insulation should be added to the solar storage tank to reduce heat gain to the basement in the summer time and to improve the annual performance of the solar thermal system.

5. The Factor 9 Home incorporated several features—an active solar space-heating system and a drain water heat exchanger—that were not able to be simulated using a single commonly available computer program. Two separate programs—HOT-2000 and RETSCREEN—were used. HOT-2000 was used to calculate the monthly space heating loads, and RETSCREEN was used to simulate the contribution of the active solar space heating system. As RETSCREEN did not have an active solar space heating module; to simulate the space heating load, the monthly space heating loads generated in HOT-2000 were converted to domestic hot water loads in RETSCREEN. A commonly available computer program that was able to compute both the space heating loads and the contribution of the active solar space heating system would simplify considerably the simulation of such houses.

Are Factor 9 Homes market-ready?

I would say yes. The components used in the house are all on the market, and with anticipated future energy price increases (in spite of the current temporary lull) the economics are favorable.

In Europe the Passiv Haus standard has gained traction. Canada needs a major promotion of Factor 9 Homes along with incentives to play catch-up.

EnerGuide Ratings

Since the inception of the EnerGuide program, first as the EnerGuide for Houses program, and more recently renamed as ecoEnergy, a total of some 500,000 homes have been evaluated and received a label. Increasingly, larger numbers of homeowners are taking action based on their evaluation. In part, the incentives associated with the work done following the energy evaluations helps to spur the actions.

Although the Federal incentive has a maximum cap of $5000 for retrofits, many provincial and regional incentives match that. Consequently, anyone undertaking a renovation that is more substantive than a cosmetic renovation should consider having the house evaluated prior to starting the renovation.

The average ecoEnergy home renovation results in 28 percent energy savings. The most common actions being taken include mechanical system upgrades, basement and attic insulation, and air sealing of homes. However, a variety of upgrade options are presented to homeowners that are tailored to the specific home.

The EnerGuide Rating for new homes is also beginning to achieve a critical mass. More than 33,000 new homes have been evaluated and labelled to date.

Last year, the estimated average EnerGuide rating for new houses in Canada was 73, while the average rating of houses that are actively participating in the EnerGuide for Houses labelling initiative is now at 77. In Ontario as of September 30, 2006, 8 percent of housing starts were labelled under ENERGY STAR with a minimum EGH rating of 78, and in Alberta 10 percent of new homes are labelled under BuiltGreen with EGH ratings between 78 and 80.

The Canadian Green Building Council's LEED for Houses program, which is to be formally launched later this year, will be accepting Energuide ratings for energy evaluations.

Five provinces (Nova Scotia, New Brunswick, Quebec, Ontario and British Columbia) have announced their intention to incorporate more stringent energy efficiency requirements within their respective building codes that will mean homes will achieve the equivalent of an EGH 80 level by 2012.

Foundation Moisture Measurement

Unprotected concrete is a hygroscopic material that can act as a path for ground moisture to travel to the interior of a house. Unprotected concrete provides the necessary moisture for mould to grow and flourish in buildings.

A study by CMHC of 405 finished basements in Ottawa, which set out to determine whether basements contributed to poor indoor air quality as a result of mould in the finishing materials, found that more than 50% of the houses had signs of moisture in the basement. Many contained mould that could be harmful to occupants, yet by building the basement correctly, it is possible to eliminate the problem.

Fab-Form Industries, the developers of fabric forming systems, have developed a simple way to measure the relative humidity in the concrete. They are calling the testing strip Damp Alert™.

This is a small (4"x6") patch that in a quick, non-destructive way will measure the surface moisture content of a material. The protective backing layer on the patch is removed, and the patch is applied on the wall (or floor) and in a few hours, the indicators will show the surface relative humidity rating. Pricing is still being worked out, but they should be in the range of $5 for a package of 2 or 3 patches.

They are setting up a non-profit website to provide information on the movement of moisture through concrete, and what can be done to prevent it.

Information:
Fab-Form Industries Ltd.
www.fab-form.com
www.damp-alert.com

NRC·CNRC

Window Shadings Reduce Residential Cooling Energy

By Aziz Laouadi and Anca Galasiu

NRC-IRC researchers conducted summer studies to determine the effect of exterior rollshutters on residential cooling energy consumption and on physical conditions associated with occupant thermal comfort. The study took place at the Canadian Centre for Housing Technology (CCHT) and compared the performance of the facility's Test House fitted with exterior rollshutters to the performance of the identical Reference House fitted with interior blinds. Both houses were equipped with a standard set of major appliances and a simulated occupancy system that replicated the daily water draws, heat and electrical loads of a family of four.

The similarity between the two CCHT houses had been verified during 18 summer days prior to the installation of the rollshutters. For the verification, the windows in both houses were equipped with interior blinds with slats in an open (horizontal or vertical) position.

Test Arrangement

The Reference House was fitted with interior, beige, horizontal, Venetian blinds on most windows and beige, vertical blinds on the patio glass door, dining room window, and stairwell window. The slats of the Venetian blinds were slightly curved and made of aluminum, while the vertical blinds were made of fabric. All interior blinds were mounted outside the window frames, leaving an open air space between the blinds and the wall incorporating the window frames.

Researcher adjusts rollshutter

All windows of the Test House, except the east-facing windows (which were kept identical to those in the Reference House), were fitted with movable rollshutters (see photo). The rollshutters were made of fixed and articulated aluminum slats (beige colour) with a sandwiched polyurethane insulation. The slats could be arranged so that they are tightly abutting (for winter use) or arranged with a small gap between the slats to admit some light and provide a view from inside (summer use). They were not designed to allow the slats to be angled, and could only be adjusted up and down in the vertical plane of the window using side railings installed on the brick walls. A rubber gasket installed between the side railings and the walls sealed the air space between the shutters and windows. The bottom of the shutters was not sealed to the window sill; it had a few holes to allow for water drainage.

Environmental conditions for thermal comfort (air temperature and velocity, globe temperature and relative humidity) were also measured at a distance of 4 feet (1.2 m) from the south-facing living room window.

The window shading measurements covered a three-week period (June 27 to July 21, 2008). The shading devices in both houses were kept closed throughout the testing period to explore the maximum effects. The slats of the rollshutters were loosely closed, leaving gaps between the slats to provide a view of the outdoors from inside the house and to admit minimum daylight indoors. The slats of the interior blinds were tightly squeezed. The set point temperature for cooling was fixed at 24°C. Indoor relative humidity was free-floating.

The testing period comprised days with various sky conditions (seven clear, three overcast, 11 mixed partly cloudy/overcast), with outdoor temperatures ranging from a minimum of +13°C during the night to a maximum +33°C during the day. Outdoor relative humidity levels were 32-99%.

Results

The results show that the rollshutters decreased the total daily energy consumption (AC + furnace circulation fan) of the Test House by ~26±10% compared to the Reference House. The daily energy used by the A/C unit of the Test House was on average 45% lower than that used by the A/C unit of the Reference House. The maximum difference in A/C daily energy use recorded was 72%, while the lowest difference was about 23%.

A maximum reduction of 80% in peak electrical demand was recorded around 2 p.m. under clear sky conditions, while for a heavily overcast day the demand reduction was still a substantial 50%. Calculated across the 21 days of the testing period, the daily maximum average reduction in electricity demand was 67%.

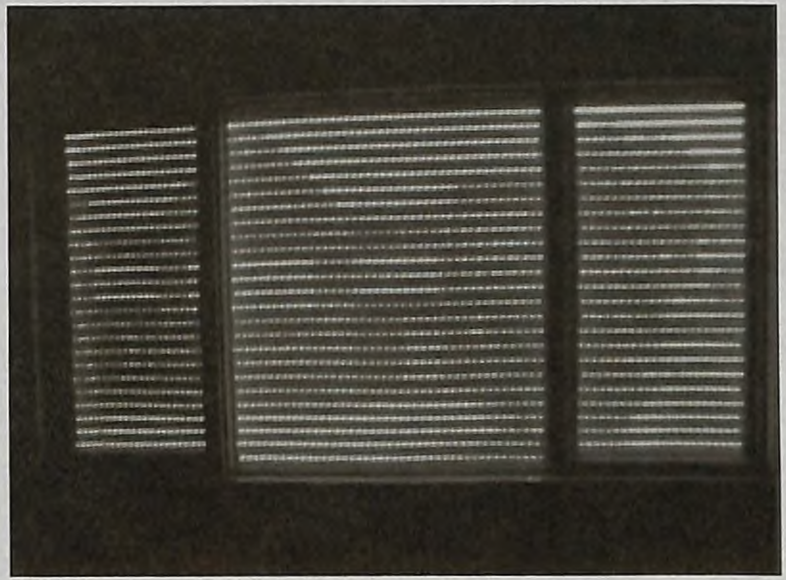
The thermal conditions near the south-facing living room window in the house equipped with rollshutters were also better than those measured in the house equipped with interior blinds, especially during night and evening hours.

These measurements have been used to calibrate a simulation model of residential energy performance. This model is being used to estimate shading effects for a greater variety of house constructions and locations, shading types, and more realistic shading positioning.

Conclusions

The fact that the Test House consistently used less electrical energy for cooling than the Reference House indicates that the exterior rollshutters were more effective shading devices than the interior blinds. Rollshutters offer the potential for reducing peak electrical demands, especially during heat waves and mid-to-late-afternoon hours, regardless of the sky condition.

Close-up of rollshutter



View from inside house with rollshutter

Additional information about the energy performance of rollshutters is available at:

http://irc.nrc-cnrc.gc.ca/pubs/ci/v12no4/v12no4_13_e.html
http://www.ccht-cctr.gc.ca/projects/solar_e.html

Dr. Aziz Laouadi is a researcher in the Indoor Environment program of the NRC Institute for Research in Construction. Ms. Anca Galasiu is a technical officer in the same program. Dr. Laouadi can be reached at 613-990-6868, or e-mail: aziz.laouadi@nrc-cnrc.gc.ca

The Canadian Centre for Housing Technology is a facility jointly operated by the National Research Council, Canada Mortgage and Housing Corporation, and Natural Resources Canada.